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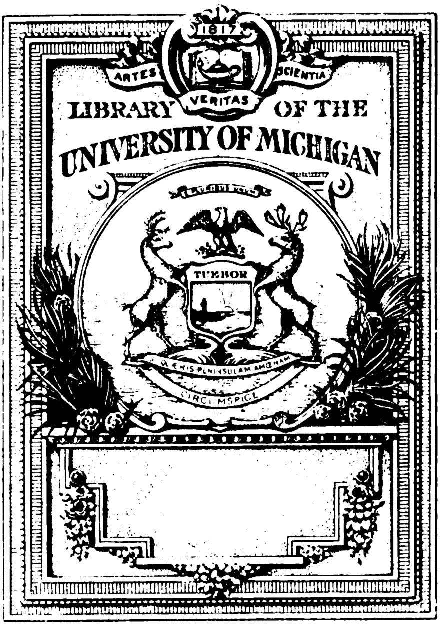
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FUEL ECONOMY IN BURNING CLAY PRODUCTS

BY

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FUEL ECONOMY IN BURNING CLAY PRODUCTS.

By A. V. Bleininger, United States Bureau of Standards, and A. F. Greaves-Walker, United States Fuel Administration.

The contents of this booklet were suggested by the necessities of the hour with reference to the fuel shortage brought on by war conditions.

The authors express the hope that the simple words employed will enable the kiln firemen as well as the owners and managing heads of plants to gain a better understanding of the subject and cause them all to cooperate to correct faulty conditions which induce waste of fuel.

Incidentally it is pointed out that fuel wastage, responsible for curtailed production, disastrously affects business returns as a whole.

IN GENERAL.

At the outset it may be said that there are many ceramic plants where efficiency prevails, and which are controlled by approved methods. Wherever this applies it can do no harm to pass on these suggestions to the firemen as a reminder to do their best at this time of fuel shortage, when a pound of coal *not* wasted means that some one badly in need may have the use of it. On the other hand, the majority of firemen are responsible for much wastage of fuel; sometimes through careless habits, sometimes through no fault of their own, but rather that of the plant manager who fails to provide proper installations.

It is not only the burning crew which should be on the alert, but also the factory manager who has the welfare of his business and his industrial family at heart. Many employers as well as workers have already learned to their sorrow what the lack of fuel means to them.

Let it be the duty of the head of the factory to see to the value he is getting out of his plant and to control its efficiency and encourage approved methods. By following these suggestions he will not only be doing what should be part of his work, but he will also insure a steadier operation of his and indirectly other plants and incidentally help his earnings and those of his employees by maintaining earning capacity, not to speak of easing the burden of those who are charged with the duty of administering fuel and transportation problems.

These elementary lessons are so worded that anyone may understand their meaning and carry them into effect; nearly all of the suggestions involve no great outlay to put into operation. They may be applied without delay and fuel conservation can begin at once.

A plant manager who does not acquaint himself with the fundamentals of burning and who does not cooperate with his burning crew is not competent to be in charge in these times, because fuel is as important as raw materials, labor, or finished products.

Let him familiarize himself with the shortcomings as well as the good points of his plant, and adopt corrective measures where necessary, as well as be able to recognize efficiency where it exists.

By carefully observing the conditions of your plant and correcting faulty installations and methods, you will effect a greater saving of fuel than by shutting down periodically or perhaps by being forced to do so because of necessity born of wasteful conditions, with the advantage of not disrupting your own and other industries.

And bear in mind that you may have to contend with one or more winters of war and the fuel situation may then be as serious as now; hence it behooves you to get busy at once in the boiler room and kiln department. *There is no surer way of gaining compound interest than by correcting wasteful conditions, for waste and loss of net profit are synonymous.*

The following recommendations are drawn up with the idea of showing where fuel may be wasted and in a general way how it may be conserved. Each plant presents its own individual problems, but the principles governing combustion and fuel and the handling of kilns remain the same, regardless of the size or type of plant.

Up to the present time any investment made for the purpose of conserving fuel was decided on the basis of what the dividends would be. *The present crisis has made it necessary to conserve fuel in every way in order that we may stay in business.*

COAL.

When coal is purchased, you receive so many heat units per ton. When this is burnt, some heat units are used to finish your ware and the remainder are wasted. This waste can not be entirely eliminated, but a great part of it can be if these conditions are looked into and followed up in the proper manner.

In normal times coal should be purchased on a basis of its heating value whenever possible. Under the present conditions, however, this is not possible in most sections of the country. *To-day the problem is not so much "how many heat units do I get in the coal which I buy," but rather "how can I get the heat units to do the utmost work in such coal as I am able to obtain." In short, you must take what you can get and make it serve you as well as possible.*

Under any circumstances it can do no harm to make ash and water determinations on each shipment. The information thus gained, if records are kept, will be valuable as a means of comparison.

Remember that both ash and water are waste, yielding no heat, but on the contrary absorbing it. Their content, therefore, should be as low as possible. Anyone can make a water and ash determination by weighing on a grocer's scale, say, 10 or 20 pounds of coal taken in smaller pieces from all over the pile and drying it on top of a boiler or around a kiln. The difference in weight evidently represents the loss due to the water. Subtract the weight of the dry coal from that of the wet, and divide the difference by the weight of the dry coal. On multiplying the result by 100, the percentage of water will be obtained. By heating this coal in any kind of tray of burned fire clay, such as a small open pottery sagger, previously weighed, and placing the whole in a kiln, the amount of ash may be readily determined.

Since the coal proper burns away during the firing of the kiln, the residue which is left must be the ash. Weigh the receptacle with its residual ash. The percentage of the ash is computed as follows: Subtract from the weight of the tray, plus ash, the weight of the receptacle. Divide this difference by the weight of the dried coal as previously determined and multiply the result by 100. This will give the percentage of the ash in terms of the dry weight of coal.

Very useful and interesting information as to the nature of the ash, whether clinkering or nonclinkering, can be gotten by inspection of the residue on the tray. A little experience will show whether or not the coal is getting better or worse with reference to the character of the ash.

Accumulate, as far as possible, coal during the summer to the extent to which you are entitled to it. Do not exceed your allotment. Store the coal as much as possible on paved or board floors, so that it may be easily shoveled off and none be lost by being crushed into the ground by horses and wagons.

Watch the sizing of coal and *use as much slack as possible.* The fine coal can be worked to advantage for the earlier part of the burn, saving the lump and coarser sizes for the heat raising and the more difficult stages.

Make every effort to know the weight of the coal used for each burn and ton of ware, so that you may know the cost of burning and compare one kiln with another. Without a system of securing this information, all attempts to save fuel will be hopeless.

Kiln Construction.

Drain your kiln yard as thoroughly as possible by putting in lines of draintile or sewer pipe. Moist kiln bottoms mean waste of fuel and time. In down-draft kilns of the well-hole type looks for leaks and short circuits to the flues leading to the center. The outside hole between the bags may be too close to the wall and unless the ware is set up close to the wall short circuits between the ware and wall will occur, the hot gases from the fire boxes passing down this space and out through the flue. Bags built over the ends of the flues may not be properly paved and thus cause leakage to the flues, besides representing poor construction. The bag walls should be kept up and not allowed to sag away from the wall, as this is another cause of short circuiting of the fire gases.

Many kilns have too much free opening where the side flues beneath the floor enter the main cross flue. Keep the openings of the mid-feather flues as small as possible without, of course, choking the draft. It is the purpose of the kiln bottom not only to bring about proper heat distribution, but also to cause enough resistance to the flow of gases so that the heat will not rush out of the kiln too rapidly. Do not depend on the damper for this purpose, as it alone can not do this work satisfactorily. If your side flues are largest, test this out by paving the bottoms first with one course and then another until the best results are obtained, or simply place loose bricks into the openings leading from the side flues to the main flue, thus partially closing the opening.

Use flat grates wherever possible, as this will enable you to fire with slack or fine coal. The grateless furnace and widely spaced inclined grates should be employed only when the coal clinkers so badly that their use is necessary. Wherever the coal permits it, flat grate bars should replace the other types of furnaces. Remember that it is not what we like to do that is essential at this time, but what we should do to help our country. Portable grates are made which can be wheeled from kiln to kiln.

All kilns should be equipped with fire-box doors, and they should be as tight as it is possible to make them. The point is that the inlet of the air above the fires should be under control, so that it may be cut off entirely or regulated to suit the requirements. Common sense, ordinarily close-fitting doors are all that is necessary. *The haphazard admission of air to the kiln is one of the most serious causes of heat loss. Remember that every pound of unnecessary air admitted into the kiln will carry away some of your heat into the stack.* This condition is especially bad in furnaces without grates, where the air is excluded by the banked-up green coal when it is most needed and allowed to enter as the coal burns down, when it is superfluous. The most effective air is that coming through the fuel bed.

Keep up the kiln bracing in good shape, so as to avoid extensive cracking and make all kiln repairs at once. Keep the small cracks inside of the kiln closed by applying a cement consisting of 80 per cent of finely ground fire bricks (of good quality) and 20 per cent of strong plastic fire clay. The fire-brick grog must pass through a 20-mesh sieve and the mixture should be made into a thin paste with the clay thoroughly worked up. This can be applied with a broom. In case the cement should not apply well to old brick walls, add about one per cent of silicate of soda (water glass) to the mixture. It is also desirable to brush on this cement all over the interior of the kiln and to close in this way many small air leaks, besides helping the kiln wall stand up better in burning.

Since much heat is lost through the kiln crowns, due to their being the thinnest portion of the kiln, it is advisable to cover them with a layer of heat-insulating material, either in the form of the bricks sold for this purpose, or a cement composed of diatomaceous earth (Kieselguhr) with a little clay to cement the mass together. Information as to where such brick can be obtained will be supplied by the Industrial Furnace Section, United States Fuel Administration, upon request. Where such material is not easily available or a less expensive method is desired, bricks made from any plastic clay admixed with 25 per cent of sawdust (by weight) and burned to the hardness of salmon brick can be made to do, though their efficiency is not nearly as good as that of the special products used for the purpose. For most cases a thickness of about 2 inches of insulation will suffice. Too heavy a layer causes the fire bricks on the kiln face to become too hot unless they are of high grade or low temperatures are used. The more refractory the bricks used in the crown are, the heavier an insulation can be applied. *In all cases it is necessary to waterproof the kiln by the use of a plastering of cement mortar* applied either direct to the insulating bricks or on top of a flat course of bricks laid upon the loose insulation. It would be well also to insulate the kiln walls when constructing new kilns, but usually this is not feasible in kilns already built. *Remember that any hot surface of the kiln continually gives off heat for which you must pay. The cooler the kiln surfaces are the less they lose.*

Do not allow side and main flues to fill up with sand, as this condition makes for long burns. The flue leading to the stack must be covered tight. Leaky flues make it difficult to control the burns properly. The damper should not be of the haphazard variety, but must fit into its slots reasonably close. This means that it should not be warped. Fire-clay slabs held together by an iron band or by means of rods running through holes in the tiles make dampers which do not warp. Hinge dampers on top of the stack are most effective in controlling draft and are much superior to the usual type of flue damper. The "air damper," which consists of an opening in the stack which is closed or opened as is found necessary, is an inefficient type.

With reference to stacks, it might be said that the ideal layout would provide one large and high stack for all the kilns of a plant. This would make possible the most efficient control of the burning operations. At any rate, the grouping of four or more kilns around one stack is very much to be desired, but the stack should be partitioned part of the height with a separate section for each flue. Cracked stacks should be repaired immediately and if necessary iron bands put around them. A leaky stack causes poor draft and fuel waste. Special attention should be given to kilns having stacks built in the walls. Every effort should be made to prevent the gases from short circuiting through the walls to these stacks instead of entering from the flues.

Setting.

All kilns should be filled to capacity and as nearly as possible up close to the crown and the setting so arranged that the ware may be burned evenly without spending too much time in "soaking."

Much valuable kiln space is lost and much fuel wasted through not filling the kiln to capacity. Experiment and see how high your ware can be set with good results. Set ware well over flue openings close to the wall to prevent short circuiting from bags.

The time of burning with round down-draft kilns may be reduced by setting loose rigs of bricks, three stretchers wide, which will cause the heat to travel downward much faster. To illustrate, in a 32-foot round down-draft kiln two such open rings may be set, the first one facing the bag walls, and the second intermediate between the first ring and the center of the kiln. This mode of setting necessitates "backing out" of the kiln. The heat will travel more rapidly through the loosely set rings and hence the bottom will heat up much faster. The bottom courses of the rings may be set tight in order to prevent the heat from escaping too readily. This method of setting will also prevent high benches from "tumbling." In square down-draft kilns, straight-open set sections may be set across the kiln, likewise, three stretchers wide. In this case also the bottom courses should be tighter.

Do not set wet or partially dried ware, as this practice lengthens the time of burning and increases the fuel consumption. The kiln is a most expensive and inefficient dryer.

Run peepholes through the kiln near the floor in order to determine during the burning how the different parts heat up. The more uniformly a kiln gains heat, the less fuel will be required in burning.

Burning Operation.

The first requirement of successful burning is sufficient draft from the very start. For this reason a kiln attached to a stack already heated will make better time than one starting with a cold chimney. Water smoking must begin promptly and no time should be lost in bringing the temperature up to 150°F.

The dryer the ware is the more rapidly can the temperature be raised to 220° F., which should be the initial kiln temperature for thoroughly dry goods. A kiln still warm from a previous burn will also permit of more rapid circulation.

When starting with a kiln attached to a cold stack, it is often well to induce draft by building a fire in the bottom of the stack or in the stack flue, or by attaching to the latter a small portable electrically driven fan. Connections can be made from the flue to the fan and back again by means of two sheet-iron goosenecks.

It is obvious that no general rules applying to every case can be given as to the best method of raising the heat during water-smoking, since the kind and size of the ware, the kind of clay, its state of dryness, and the size and type of kiln must be considered. Several examples might be given as to the water-smoking practice used in commercial kilns. In a 32-foot round down-draft kiln set with brick the best procedure was found to be as follows: The temperature is brought at once to 150° F. and maintained at this point for 12 hours; it is then raised to 220° F. in 6 hours and held there for 6 hours. From this point on the temperature is raised steadily at the rate of 25° F. per hour.

In another 32-foot round down-draft kiln, burning building brick, the practice is to maintain the fire in the bottom of the furnace, the coal being off the grate, on the furnace floor for 30 hours, which corresponds to the length of time of water-smoking. In both cases the kilns started with cold stacks. In firing small sewer pipe in a down-draft kiln the initial temperature was 150° F., which was raised to 220° F. in 21 hours, and from here on to 390° F. in 13 hours In the same kilns large, heavy pipe was raised from 150° F. to 240° F. in 24 hours, and was maintained at this point for additional 27 hours. From here on the heat was raised to 390° F. in 6 hours. Considering the water-smoking period as completed at 390° F., this stage consumed 34 hours with the small pipe and 51 hours for the large pipe.

As a rule too much time is wasted in getting the water-smoking started, principally due to poor initial draft and holding the kiln at low temperature for too long a period. It is very necessary to control the water-smoking temperatures either by means of thermometers made for this purpose or pyrometers. Without their use the burner is practically helpless, since he either wastes time by being overcautious and maintaining too low a temperature or he may cause serious damage to the ware by overheating it at one time or another.

The completion of water-smoking may be determined by inserting a cold iron rod into the kiln flue. A pipe closed at one end and filled with cold water used in the same way gives a still more sensitive test. Moisture on the rod or pipe indicates that the water-smoking is not complete. Completion of water-smoking means that the heat should at once be raised, the most generally satisfactory rate being about 25° F. per hour, up to 400° F. Beyond this point raise the heat more rapidly, say 35° F. to 40° F. per hour. For many clays this steady rate can be maintained throughout the burn up to the finishing or soaking temperature. Clays more difficult to oxidize should be heated up at the rate given above up to 1,300° F.; where the temperature should be held, admitting as much air as possible between fires until the black core has disappeared, which point should be established by drawing frequent samples from the kiln near the bottom. As soon as this condition is reached the heat can be raised quite rapidly at the rate of 35° F. or 40° F. per hour until the finishing temperature is reached, which must be held until the bottom has been uniformly brought to the proper temperature.

For most clays made into bricks by the stiff or soft mud process, and kilns 32–36 feet in diameter, *the time for burning should not exceed five days.* Many plants do as well as this and even better, provided, of course, that the ware is set perfectly dry. Such ware as drain tile can be burned in two days. The one essential point is sufficient draft and ample grate area. Too small a grate surface and poor draft invariably means long firing and large coal consumption, as well as uneven burns. For the average clays used for making the crude clay products the grate area in square feet should be equal to 1.5 per cent of the interior kiln volume in cubic feet. Another method of arriving at this is to allow 1 square foot of fire-box area to from 4 to 8 square feet of kiln-floor area. For refractories the ratio should be 1 to 4, for clays finishing at low temperatures it should be 1 to 8.

Means of Controlling the Burning.

Besides the thermometers used during water smoking, pyrometers are of very great service in controlling the rate of firing. In fact, by no other means would it be possible to determine this factor. The use of such instruments is essential if the time, and with it the fuel consumption, is to be reduced to the minimum. There are on the market a number of reliable pyrometers, so that no time need be taken up in discussing them. Pyrometer systems should always be installed by an expert. Many outfits have failed through improper installation.

In the majority of cases base metal couples are used in the firing of red-burning clays, and these can be made to give good service, provided they are well protecter by means of clay tubes and not exposed to the hottest part of the kiln. Platinum-platinum rhodium couples serve their purpose best when inserted through the crown of the kiln, using a heavy fire-clay protection tube. The base metal couples should be placed in position at the middle or toward the bottom of the kiln. One standard couple should be kept ready for testing the working couples as to their accuracy, since thermo elements undergo constant changes. In many plants the couples are used too long and should be replaced more frequently. Information concerning the making of cheap couples by users of pyrometers (for low temperatures) may be had by applying to the industrial-furnace section. Information concerning the proper treatment of thermo couples, their calibration, and the errors involved in using them may be likewise obtained from the above bureau.

It is necessary to work out a schedule for the burners which can be followed by the use of pyrometers. This schedule may be made out in the form of a table or a curve. A standard size coal shovel should be used and the number of shovels to be fired at definite intervals prescribed for each stage of the burn. Clinkering of the grates likewise must be done at definite times. Unless the firing is thus systematized or standardized it will be difficult to make the necessary changes or to compare one burn with another. In this manner it will be quite easy to shorten the firing time as much as the clay and the kind of product permit.

Draft Control.

It is not uncommon to find a plant where a temperature curve is followed very carefully without showing any saving in fuel. This is nearly always due to excessive flow of the gases from the kiln to the stack. While during water smoking we have a deficiency of draft, toward the latter end of the firing there is usually an excess. It is evident that under such conditions too much heat will be lost at this time, with the result that the kiln bottom can not be brought to the proper temperature without the use of an excessive amount of fuel. This condition is made much worse wherever the kiln bottom is too open, allowing the hot gases to leave without meeting sufficient resistance. Such a faulty kiln bottom should be at once adjusted.

A certain amount of control is still necessary in order to regulate the outflow of gases to the desired degree. For this purpose a draft gage is employed which must always be connected to the stack flue between the kiln and the damper. In inserting the iron pipe the latter must be either flush with upper surface of the flue or allowed to communicate with a space, say equal to half a brick left out in the arch of the flue. In this fashion we can measure what usually corresponds to "draft." Draft gauges are now supplied on the market in several forms and should read to one-hundredth inch of water gauge. Information as to pyrometers and draft guages can be obtained from the industrial-furnace section.

In using the damper, attention is called to the fact that the checking effect is not proportional to the depth to which it is let down, a fallacy still commonly accepted. When closing off the top section of the flue, but little effect is produced upon the draft, since the gases pass through the opening merely with increased velocity. On the other hand, the damper when close to the flue bottom operates too effectively, and is apt to check the draft too much, due to the production of eddy currents. The damper, therefore, becomes really effective only through the middle section of the flue. A damper attached to the top of the stack would be more effective than the ordinary flue damper. Far closer control of the damper is necessary than is usually assumed, and hence it must be well fitting and the openings must be kept as tight as possible. A scale board showing the depth to which the damper has been dropped and graduated in inches and half inches is of help in controlling the draft. For each kiln a certain maximum draft should not be exceeded. For some kilns this value has been found to be equal to 0.17 inch water gauge.

Where a pyrometer is used, it is very easy to fix the proper dampering of the kiln. If upon letting down the damper to a certain depth, the temperature of the lower part of the down-draft kiln continues to rise, this would indicate that the draft can be reduced still more. This procedure is continued until the kiln ceases to gain in heat. This point then indicates the limit to which the reduction in draft may be carried. The amount of coal fired may be cut down as the damper is lowered and the temperature-time schedule followed as laid down.

The rate of settling of the ware in the kiln should invariably be determined in the case of bricks. The measurements must be made every three hours during the last stage of the burn. Where the total settle is, say, 12 inches, its amount per 12 hours should not exceed 3 inches, but it also should not be less than one-half inch for the same period. Obviously no general rules can be given for all clays, since the shrinkage varies widely. The information obtained through the settle measurements consists in showing the uniformity of the burn and especially the progress in bringing the bottom of down-draft kilns to the final temperature.

The use of Seger cones (well protected from impinging flame) is advised for all kinds of burns, using higher numbers for the top, to prevent overfiring and the correct number for complete maturity on the bottom. Draw trials for color and shrinkage are also desirable. Draw trials pressed on a small hand press and provided when dry with scratch marks a definite distance, say, 3 inches apart, afford a very valuable indication of the progress of the burning process in the clay. These should be placed in the softer burning parts of the kiln, say, near the bottom of a down-draft kiln and withdrawn at 3-hour intervals, during the last 24 or 30 hours of the burn. The measurement of the contraction between the shrinkage marks by means of an accurate vernier caliper thus results in a valuable index as to the degree of burning.

In the use of coal in kiln firing one of the great heat losses is that due to excess of air admitted to the kiln, especially over the fires. *The smoke passing through the stack is not necessarily a sign of much heat loss, but it is the entirely smokeless firing of bituminous coal which may be responsible for a large waste of fuel, through the admission of excessive amounts of air.* This is contrary to the usual opinion, but is borne out by actual facts. It is through the proper use of the damper, by keeping the kiln doors closed as tight as possible, and by avoiding all leaks that the air excess must be kept down to the minimum. Avoiding the use of any large air excess during the heat raising stage of the burn will do much to cut down the time of firing. By means of gas analyses, for which samples are taken from the flue close to the kiln, it is possible to determine the actual amount of air excess, and to cut it down to a reasonable figure by using the means already pointed out. To a certain extent this condition may be estimated by the draft gauge readings as well.

In order to illustrate the saving of fuel which may be effected by adopting systematic burning, two charts are given here taken from actual kiln records. It will be noted that the final temperatures necessary in firing this clay are considerably higher than those required for the ordinary red burning clays and that, hence, with such materials it should be possible to cut down the time of firing and the amount of fuel used to lower figures than were possible in the case illustrated.

Chart I represents face brick kiln records. Here curve 7 shows the latter part of the old system of firing, which required 8 days and 16 hours. Curve 4 shows the shortest time made, 4 days and 21 hours, but curve 5 was found to represent the most economical system of firing, as in holding the heat for the last 29 hours, but little fuel was consumed, since it meant merely the replacing of the heat radiated from the kiln.

It may be taken to be a general rule that the faster the heat is raised, the longer must be the period of soaking.

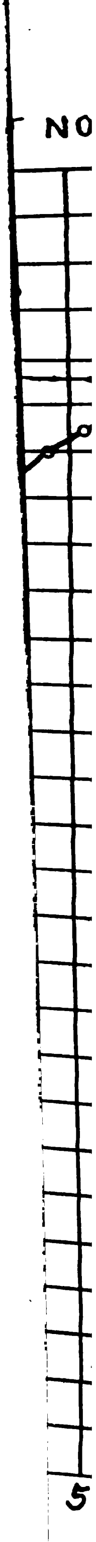
If the heat is raised slowly enough no long soaking may be necessary, as the temperature becomes equalized during the heating up. Thus, curve 5 would represent good general practice. Of course, where a clay requires special care in oxidation, a halt must be made at 1,300° F. to complete this phase of the firing. *The mode of firing shown by curve 5 (5 days and 10 hours) resulted in a saving of fuel of 36.5 per cent.*

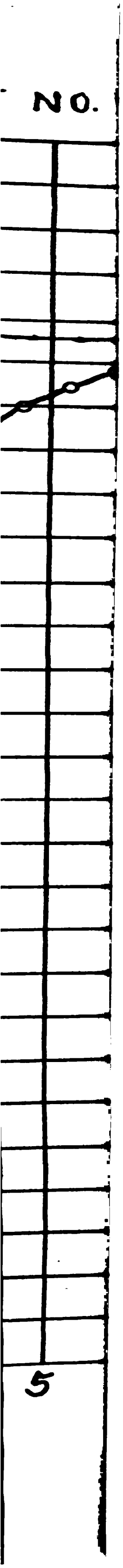
Chart II represents the firing curves of sewer pipe kilns as finally adopted. Here curve 1 is that for small pipe, 62 hours, and curve 2 for heavy pipe, 96 hours.

It should be understood, of course, that not all saving is due to the shortening of the time of burning but that control of the draft and systematized firing are factors equally essential.

The use of complete records showing the time, temperatures, settle, periods of firing, time of clinkering, and the amount of coal used are of prime importance in effecting fuel economies.

Note.—The authors are indebted to Frank H. Riddle, Edmund Eckart, and Andrew B. Duryee for suggestions.

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